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DEVELOPMENT AND EVALUATION OF NONMETALLIC MATERIALS FOR BELT LINKS

Thomas J. Koehler

November 1974

TECHNICAL REPORT

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Selected plastic and elastoplastic materials were investigated for potential use as small arms and aircraft armament belt links. In this study only castable materials were evaluated because of the ease of chemical modification and simplicity of molding into links. A 7.62mm, M13 link, was used as a model to cast prototype links. Two types of epoxy resins with high tensile strength and low elongation were selected as the best available base materials to modify for links.

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All material combinations tested were found to have excessive spring yield characteristics when molded into open-loop links. The epoxy closed loop link was found to have more than twice the tensile strength of the open-loop steel control link in the belted configuration. Plastic links did not corrode and leave rust scale deposits on cartridge cases as found on steel linked cases after the water immersion test. The epoxy links maintained approximately 70 percent of their tensile strength after a 200 hour accelerated aging test in the Weather-Ometer. The epoxy material reduced the link weight by 30 percent when compared to the current M13 steel link.

CONTENTS

OBJECTIVE

The object of this work was to establish the feasibility of using plastic materials for small arms and aircraft armament belt links, and to develop materials for this purpose.

BACKGROUND

Previous attempts to use plastics or elastoplastics for conventional links have failed because the materials lacked the capacity to meet the high strength-to-volume ratio required for their operation in automatic weapon systems. However, new types of elastoplastics, thermosets, and thermoplastics are claimed to have sufficient strength for links. These materials will be evaluated and modified in an attempt to meet the requirements of current metallic links used in weapon systems.

APPROACH

Plastics and elastoplastics listed in Table 1 were selected as potential materials for use in the fabrication of links. Physical properties of these materials are shown in Table 2. Samples of these materials were requested from manufacturers for laboratory evaluation and for modification to meet link requirements. The decision was made to evaluate castable materials in this laboratory study because they are relatively easy to modify with reinforcing fibers, and simple molding procedures could be used to prepare prototype links. Current link requirements for automatic weapon systems were reviewed and are presented in Table 3. The maximum tensile load for assembled links was 800 pounds for the M17A1 link used with the M61 automatic gun.

Test specimens were made from the plastic and fiber combinations shown in Table 4. Specimen thickness was approximately 0.070 inch to simulate the thin sections found on all metallic link systems. Standard ASTM D 638 tensile test specimens were prepared with a "tensilkut" apparatus. Specimens were evaluated for both tensile strength and elongation.

After completion of the physical tests on material specimens, prototype plastic links were designed to simulate actual belt links. The metallic cartridge belt link, 7.62mm, M13, as described in Military Specification MIL-L-45403, was selected as the model for cast prototypes. This link is currently used in the M60 machine gun and is easily adaptable to laboratory casting techniques. A silicone rubber mold was prepared for use in the casting of links from the selected materials. Two selected resin systems were chosen for casting; one was a reinforced flexible epoxy and the other was a diglycidyl ether of bisphenol. These resins were cured with selected hardeners and reinforced with glass, carbon, or a combination of glass-carbon fibers. Physical properties of the materials, when molded into links, were obtained to select the best systems for evaluation under severe environmental conditions. Selected link systems were exposed to both natural and accelerated aging conditions, and also to common solvents typically found in the proximity of automatic weapons.

TABLE 1
PLASTICS SELECTED AS POTENTIAL LINK MATERIALS

Injection and/or Compression-Molding Grade

Thermoplastic	Thermoset
Acetal	Alkyd
Nylon	Epoxy
Polyaryl Sulfone	Phenolic
Polyphenylene Sulphide	Polyester
Polysulfone	

Castable Grade

Thermoplastic	Thermoset
Nylon	Epoxy
	Phenolic
	Polyester
	Polyurethane
	Silicone

TABLE 2
PROPERTIES OF SELECTED LINK MATERIALS

	Tensile(psi)		Elongation(%)		Flexural Yield(psi)		Heat Resistance (Continuous °F)		Solvent Resistance		Effect of Sunlight		Water Absorption (%)	
	UNFILLED	GLASS FILLED	UNFILLED	GLASS FILLED	UNFILLED	GLASS FILLED	UNFILLED	GLASS FILLED	UNFILLED	GLASS FILLED	UNFILLED	GLASS FILLED	UNFILLED	GLASS FILLED
Thermoplastics														
Acetal(copolymer)	8,800	18,000	60-75	3-4	13,000	26,000	220	220	Excell.	Excell.	Chalks	Chalks	0.22	0.29
Nylon 6	7,000 12,400	13,000	100-400	10-100	7,000 15,000	7,000 17,000	175 250	180 300	Good	Good	Slight	Slight	1.3 1.9	1.5
Nylon 6/6	9,000 12,000	19,500 26,000	60-300	5-10	No Break	28,000 30,000	180 300	-	Good	Good	Slight	Slight	1.5	0.65 0.75
Nylon6/10	6,500 8,600	13,000 35,000	65-300	1.5-10	No Break	15,500 40,000	160 250	300 400	Good	Good	Slight	Slight	0.4	0.2 2.0
Polyaryl Sulfone	13,000	-	13.0	-	17,200	-	500	-	Good	-	Slight	-	1.8	-
Polyphenylene Sulphide	10,600	21,400	3.0	3.0	20,000	37,000	400 500	400 500	Excell.	Excell.	-	-	-	-
Polysulfone	10,200	-	50-100	-	15,400	-	300 345	-	Soluble Aromatic	-	Medium	-	0.22	-
Thermosets														
Alkyd	-	4,000 9,500	-	-	-	15,000	-	450	_	Fair to good	-	None	-	0.05 0.25
Epoxy	4,000 13,000	10,000 30,000	3-6	4	13,000 21,000	10,000 60,000	250 550	300 500	Good	Good	None	Slight	0.08 0.15	0.05 0.20
Phenolic	5,000 9,000	-	1.5-2.0	-	11,000 17,000	-	160	-	No Effect	-	Slight	-	0.2 0.4	-
Polyester	6,000 13,000	3,000 50,000	5	0.5-5.0	8,500 23,000	7,000 60,000	250	300 350	Fair	Fair	Slight	Slight	0.15 0.60	0.01 1.0
Polyurethane	175 10,000	-	100-1,000	-	-	-	190 250	-	Excell.	-	Slight	-	0.02 1.5	-
Silicone	350 1,000	4,000 6,500	100-1000	-	-	10,000 14,000	500	600	Swells	Fair	None	Slight	0.12	0.1 0.2
Silicone (Asbestos Filler)	28,000 35,000	-	-	-	30,000 35,000	-	-	-	Fair	-	Slight	-	-	-

Reference: Modern Plastics Encyclopedia,
Vol. 49/No. 10A, 1972-1973, pp. 142-164

TABLE 3
LINK REQUIREMENTS FOR AUTOMATIC WEAPON SYSTEMS

LINK	WEAPON SYSTEM	SPECIFICATION	APPLICABLE DRAWINGS	TENSILE LOAD (LB.) ASSEMBLED	ALLOWABLE ELONGATION (IN.) AFTER TEST LOAD (LB.)
7.62mm, M13	M60 Machine Gun	MIL-L-45403	7268389	-	Max. of .008" after 35 lb.
20mm, M10	M24 Auto. Gun	MIL-L-11536B	7238242	125	-
20mm, M12	M39 Auto. Gun	MIL-L-12997C	7147028 7548085	600	-
20mm, Mark 2	-	MIL-L-16727C	-	250	Max. of .010" after 250 lb.
20mm, M14A1	M61 Auto. Gun	MIL-L-45194B	7191530 7190180 7190471 11010274 11010276	440	Max. of .02" after 350 lb.
20mm, M17A1	M61 Auto. Gun	MIL-L-45456B	7268373 11010333	800	-
20mm, XM22	M61 Auto. Gun	-	8447607	-	-
30mm, XM23	XM140	-	8445027	-	-
40mm, M16	M5 Armament Subsystem	SAPD-251B	7791812 8444942 7791831 8444943	200	-

TABLE 4
CASTABLE GRADE PLASTICS AND FIBER REINFORCEMENTS SELECTED FOR EVALUATION

Type Plastic	Material Code	Manufacturer	Unfilled	Cut Fibers 30% Glass By Volume	Cut Fibers 30% Carbon By Volume	Woven Fabric Glass	Woven Fabric Carbon	Woven Fabric Graphite
Epoxy	Epon Resin 820, DETA Cure	Shell Chemical Co. New York, N.Y.	X	X	X			
Epoxy	RN1200 Resin, EA 8 Hardener	Conap, Inc. Allegany, N.Y.	X	X	X			
Epoxy	TC9-6175 Resin, TC9-6175 Hardener	Hysol Div., Dexter Corp. Olean, N. Y.	X	X	X	X	X	X
Epoxy	Upox 468XX	Isochem Lincoln, R. I.	X	X	X			
Polyester	R18-104A Hetron 92C Resin, Peroxide Cure	Durez Div., Hooker Chemical Corp. N. Tonawanda, N. Y.	X	X	X	X		
Polyurethane	CPR 2126N Resin, Isocyanate Cure	Upjohn Co. CPR Div. Torrance, Calif.	X	X	X			
Polyurethane	Flexane 85, Two Components	Devcon Corp. Danvers, Mass.	X			X		

Type Reinforcements	Material Code	Manufacturer
E Glass chopped strand with a silane binder, 1/4" length	CS-308	Johns-Manville Fiber Glass Inc. - Waterville, Ohio
Carbon Fiber 1/4" length	CFA1/4	Hitco Materials Div. - Gardena, Calif.
Glass woven fabric	43/768	Hess Goldsmith & Co. - Altavista, Virginia
Carbon woven cloth	CCA-1	Hitco Materials Div. - Gardena, Calif.
Graphite woven cloth	GSGC-2	Graphite Products Div. - Carborundum Co. - Sanborn, N. Y.

Links made of the most promising material combinations were sent to both an open sun and rain forest site at Panama for exposure and for comparison to links stored in the laboratory.

A steel injection mold for the M13 link was designed, on the basis of the results of this project.

RESULTS AND DISCUSSION

Plastics and elastoplastics received from suppliers were evaluated without fiber reinforcement before modification, as shown in Table 5. The tensile strength and elongation of the epoxies were found to be in agreement with data published in Modern Plastics Encyclopedia, Vol. 49/No. 10A, 1972-1973. One of the urethanes, U2126N, had a tensile strength coinciding with published data, but this urethane showed a 95 percent lower elongation at break. The nonreinforced polyester evaluated was extremely brittle and its properties showed poor correlation with published data.

The materials shown in Table 5 were selectively reinforced with carbon fibers, glass fibers, carbon fabric, glass fabric, and graphite fabric. In general, physical properties of plastics filled with cut fibers were inferior to unfilled parent materials. This inferior state was due to resin voids at intersections of reinforcing fiber bundles that severely weakened the test specimens. Various methods were attempted to remove resin voids; these included vacuum, heat, and commercial bubble-dispersing agents. All techniques removed large bubbles in the reinforced specimens, but failed to eliminate small voids.

Test specimens with a woven substrate were superior in physical strength to nonreinforced controls. A material of TC-9-6175 epoxy and woven glass cloth was 80 percent stronger in tensile strength than the original nonreinforced material. Carbon and graphite fabrics also improved the tensile strength of materials made with the TC-9-6175 resin. The elongation of all unfilled materials tested was five percent or less of original dimensions at break, with the exception of the flexible polyurethane(85). Addition of reinforcing fibers or woven fabrics reduced elongation slightly.

Prototype M13 links were molded so that selected plastic links could be compared with the standard metallic link. Silicone rubber molds as shown in Figure 1 were used in the preparation of plastic links. The complete mold system required to form the three-loop link consisted of two body cavities and two removable mandrels. Both, the open and the closed-loop plastic links prepared from test materials, and the currently used M13 metallic link are compared in Figure 2.

Cursory tensile tests performed on the plastic open-loop links indicated that the loops would "relax" or show permament set after being loaded with ammunition. The open-loop links assembled into a belt had excessive spring yield between links that could prevent proper cycling in a typical automatic delinking mechanism. The excessive spring yield of all plastics tested, regardless of the type or amount of reinforcing fibers incorporated into the resin,

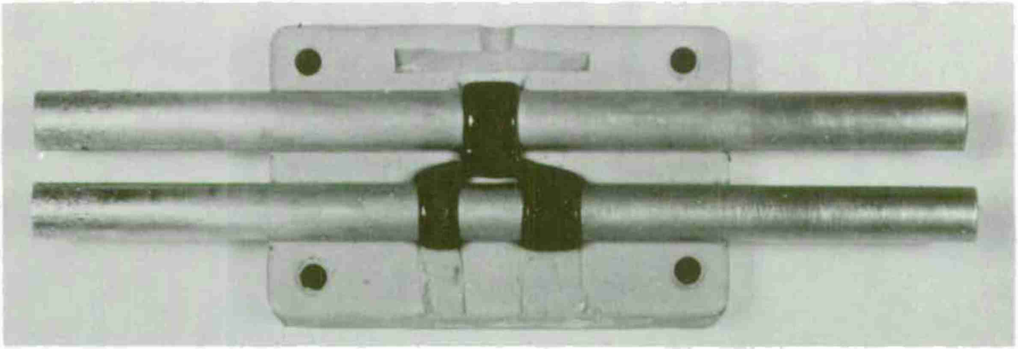
TABLE 5

PHYSICAL PROPERTIES OF LABORATORY PREPARED LINK MATERIALS

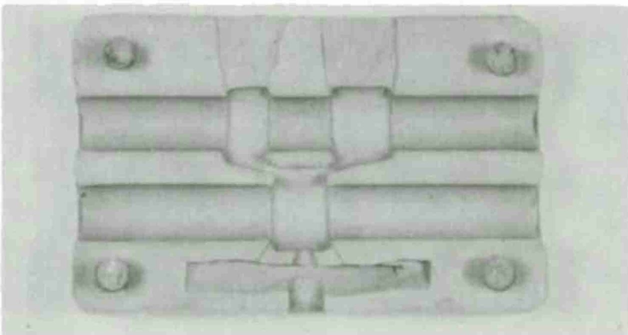
RESIN TYPE	RESIN CODE	REINFORCEMENT BY VOLUME(%)	SPECIMEN THICKNESS (IN.)	BREAKING STRENGTH (LB.)	ELONGATION AT BREAK, (%)	TENSILE STRENGTH(psi)
Epoxy	820	None	0.070	363	5	10,312
"	820	30-Carbon	0.081	170	2	4,153
"	820	30-Glass	0.074	202	1	5,380
Epoxy	RN-1200	None	0.059	294	4	9,858
"	RN-1200	30-Carbon	0.065	141	1	4,254
"	RN-1200	30-Glass	0.067	226	1	6,666
Epoxy	TC 9-6175	None	0.069	288	4	8,180
"	TC 9-6175	30-Carbon	0.072	206	2	5,621
"	TC 9-6175	30-Glass	0.069	270	2	7,598
"	TC 9-6175	Carbon Fabric	0.068	305	2	8,846
"	TC 9-6175	Glass Fabric	0.069	504	5	15,360
"	TC 9-6175	Graphite Fabric	0.068	330	3	9,428
Polyester	R18-104	None	0.063	73	0.7	2,283
"	R18-104	30-Carbon	0.072	66	0.5	1,783
"	R18-104	30-Glass	0.069	114	0.6	3,220
"	R18-104	Glass Fabric	0.069	266	2	7,600
Urethane	U2126N	None	0.073	277	5	7,480
"	U2126N	30-Carbon	0.074	210	3	5,541
"	U2126N	30-Glass	0.075	272	2	7,170
Urethane	85	None	0.079	29	300	750
"	85	Glass Fabric	0.150	145	33	1,900

NOTE: All specimens were tested on an Instron Tensile Tester using a 0.2 inch strain rate and a 3 inch gauge length between jaws.

FIGURE 1 SILICONE RUBBER MOLD USED TO CAST TEST LINKS



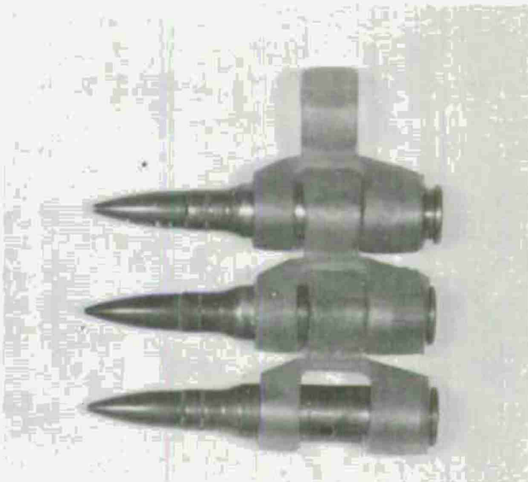
Mold Half Showing Link and Mandrel Arrangement



Mold Half Showing Link Cavity

FIGURE 2 COMPARISON OF OPEN AND CLOSED LOOP PLASTIC M13 TEST LINKS WITH THE STANDARD METALLIC M13 BELT LINK

M13 PLASTIC TEST
LINK(Open Loop)



M13 PLASTIC TEST
LINK(Closed Loop)

M13 METALLIC BELT
LINK(MIL-L-45403)

precluded the use of open-loop links in present-day automatic weapon systems. Therefore, all materials evaluated were prepared in the geometry of a closed-loop link with the use of either a castable epoxy or a modified epoxy resin. Resin systems, hardeners, flexibilizers, and reinforcing fibers used in the casting of prototype test bed links are outlined in Tables 6 and 7. Links prepared from resins with aminoethyl piperazine and metaphenylene diamine hardeners had the highest tensile strengths in combination with the lowest elongation of any plastic link tested at the required 35-pound load, and again at ultimate link failure.

All resins, when filled with reinforcing fiber combinations were found to have some loss of tensile strength when compared with the unfilled materials. This was caused by air voids within the fiber bundles that permitted resin voids to accumulate in the link. The strongest resin-fiber combination was prepared from the EPON 820 epoxy resin, aminoethyl piperazine hardener, and 30 percent by volume of 1:1 carbon-E glass fiber mixture. The M13 metallic control link had the highest elongation of any of the links evaluated, and had lower tensile strength than the majority of the plastic links tested.

Five types of links were selected from Tables 6 and 7 for exposure to accelerated aging in the Weather-Ometer and for contact with typical military classes of chemical solvents. Physical properties of the links after these exposures are shown in Table 8. Links exposed in the Weather-Ometer for 100 hours retained their original strength with the exception of the link prepared from the modified epoxy commercially filled with a glass fiber. All plastic links lost over 20 percent of their tensile strength after the 200-hour Weather-Ometer exposure. However, all plastic links, with the exception of the commercial, glass-filled, test specimen, were still considerably stronger than the metallic control link. The metallic link had considerable corrosion located on surfaces that came in contact with the cartridge case after the 200-hour exposure, but this corrosion did not affect its physical strength.

Links prepared from the Epon 820 epoxy resin and hardened with aminoethyl piperazine were resistant to deterioration after exposure to the chemicals listed in Table 8. All other plastic links were affected, by varying degrees, to one or more of the solvents. The most severe deterioration occurred on links prepared from the modified epoxy when subjected to the seven-day water-immersion test. The metallic control links became severely corroded in tap water, but again this corrosion did not affect the physical properties of the link. Plastic link elongation did not change appreciably after exposure in the Weather-Ometer and contact with solvents, with the exception of the modified epoxy resin cured with the amino piperazine hardener. This link material was extremely elastic after immersion in tap water, showing link elongation of over 0.25 inch at virtually zero tensile load. Change in weight of links after immersion in solvents, as presented in Table 9, was negligible except for the modified epoxy links that were immersed in water.

Typical failure patterns, when links were stressed to ultimate failure, are shown in Figure 3. The cast epoxy links without reinforcing fibers failed through the arch that interconnects the three loops. Slight variations of

TABLE 6

PHYSICAL PROPERTIES OF LINKS CAST FROM AN EPOXY RESIN* WITH SELECTED HARDENERS AND REINFORCING FIBERS

M13 TYPE PLASTIC LINK SYSTEM	UNFILLED MATERIAL			FILLED, 30%E GLASS(1/4" Fiber)			FILLED, 30%E CARBON(1/4" Fiber)			FILLED, 30% CARBON/GLASS MIXTURE		
	Tensile	Elongation(in.)		Tensile	Elongation(in.)		Tensile	Elongation(in.)		Tensile	Elongation(in.)	
HARDENER	(Ult., lb)	@35 lb.	Ult.	(Ult., lb.)	@35 lb	Ult.	(Ult., lb.)	@35 lb.	Ult.	(Ult., lb.)	@35 lb.	Ult.
Diethylenetriamine, (DETA)	90	0.034	0.061	-	-	-	-	-	-	-	-	-
Aminoethylpiperazine, (ISOCHEM#13)	244	0.032	0.115	-	-	-	161	0.036	0.092	200	0.032	0.091
Metaphenylenediamine eutetic, (ISOCHEM 15AX)	234	0.031	0.101	80	0.033	0.054	40	0.039	0.043	-	-	-
DETA - #13	157	0.040	0.100	-	-	-	86	0.036	0.061	-	-	-
DETA - 15AX	71	0.042	0.060	-	-	-	116	0.041	0.078	-	-	-
#13 - 15AX	129	0.032	0.074	-	-	-	-	-	-	-	-	-
DETA - Polyester resin flexibilizer	121	0.038	0.078	-	-	-	100	0.035	0.065	-	-	-
15AX - Polyester resin flexibilizer	192	0.035	0.097	103	0.032	0.060	113	0.033	0.065	153	0.033	0.075

*Diglycidyl ether of bisphenol diluted with 2-5% phenyl glycidyl resin (Shell Epon 820)

TABLE 7
PHYSICAL PROPERTIES OF LINKS CAST FROM A MODIFIED EPOXY RESIN*
WITH SELECTED HARDENERS AND REINFORCING FIBERS

M13 TYPE PLASTIC LINK SYSTEM HARDENER	UNFILLED MATERIAL			FILLED, 30% E GLASS (1/4" FIBER)			FILLED, 30% CARBON(1/4" FIBER)			FILLED, 30% CARBON/ GLASS MIXTURE		
	Tensile (Ult., lb)	Elongation(in) @35lb	Ult.	Tensile (Ult., lb)	Elongation(in) @35 lb	Ult.	Tensile (Ult., lb)	Elongation(in) @35lb	Ult.	Tensile (Ult., lb)	Elongation(in) @35 lb	Ult.
Diethylenetriamine (DETA)	97	0.035	0.065	—	—	—	—	—	—	—	—	—
Aminoethyl piperazine (Isochem #13)	279	0.030	0.146	141	0.036	0.095	—	—	—	—	—	—
Metaphenylene diamine eutetic (Isochem 15AX)	102	0.033	0.064	—	—	—	—	—	—	—	—	—
DETA - 15AX	129	0.035	0.077	—	—	—	81	0.037	0.058	70	0.036	0.054
DETA - 15AX - Polyester resin	176	0.035	0.102	—	—	—	—	—	—	—	—	—
15AX - polyester resin	94	0.037	0.063	—	—	—	—	—	—	—	—	—
Steel Production M13 Control Link	78	0.076	0.0233	—	—	—	—	—	—	—	—	—

* Reinforced polymeric reaction of polyester urethane and epoxy novolac (Isochem Upox 468XX)

TABLE 8

PHYSICAL PROPERTIES OF LINKS AFTER ACCELERATED AGING AND EXPOSURE TO COMMON CHEMICAL REAGENTS

	Link Material Code (See Note)					
	1	2	3	4	5	6
Control Links Std, Conditions ASTM-E-73°F. 50% R.H.						
Tensile, Ult. lb	78	279	141	244	234	153
Elongation, in						
@35 lb	0.076	0.030	0.036	0.032	0.031	0.033
Ult.	0.233	0.146	0.095	0.115	0.101	0.075
Link Aged By Accelerated Techniques Aged 100 hrs. Weather-Ometer ASTM-G23-69						
Tensile, Ult. lb	84	225	16	267	233	132
Elongation, in.						
@35 lb	0.067	0.034	-	0.034	0.032	0.030
Ult.	0.247	0.151	0.245	0.120	0.097	0.063
Link Aged By Accelerated Techniques Aged 200 hrs. Weather-Ometer ASTM-G23-69						
Tensile, Ult. lb	80	222	19	177	139	108
Elongation, in.						
@35 lb	0.074	0.038	-	0.029	0.032	0.029
Ult.	0.251	0.146	0.250	0.079	0.071	0.054
Links Exposed to Common Military Chemical Reagents						
7-Day Immersion Tap Water						
Tensile, Ult. lb	81	60	11	237	240	177
Elongation, in						
@35 lb	0.077	0.095	-	0.031	0.033	0.028
Ult.	0.290	0.201	0.240	0.147	0.109	0.077

TABLE 8 (Cont.)

PHYSICAL PROPERTIES OF LINKS AFTER ACCELERATED AGING AND EXPOSURE TO COMMON CHEMICAL REAGENTS

	Link Material Code (See Note)					
	1	2	3	4	5	6
Links Exposed to Common Military Chemical Reagents — 7-Day Immersion Saturated Sodium Chloride Solution						
Tensile, Ult. lb	80	236	10	245	282	155
Elongation, in.						
@35 lb	0.075	0.034	-	0.032	0.030	0.028
Ult.	0.232	0.130	0.236	0.123	0.113	0.067
Links Exposed to Common Military Chemical Reagents — 7-Day Immersion Type II Aromatic Hydrocarbon, TT-S-735						
Tensile, Ult. lb	79	278	148	264	248	95
Elongation, in.						
@35 lb	0.070	0.030	0.032	0.030	0.029	0.029
Ult.	0.248	0.126	0.073	0.118	0.097	0.060
Links Exposed to Common Military Chemical Reagents — 7-Day Immersion Type III Aromatic Hydrocarbon, TT-S-735						
Tensile, Ult. lb	84	220	118	277	200	128
Elongation, in.						
@35 lb	0.070	0.032	0.036	0.031	0.028	0.030
Ult.	0.247	0.105	0.071	0.128	0.082	0.071
Links Exposed to Common Military Chemical Reagents — 7-Day Exposure Thin Film Of MIL-L-46000 Lubrication Oil						
Tensile, Ult. lb	81	280	145	217	219	131
Elongation, in.						
@35 lb	0.076	0.033	0.032	0.033	0.032	0.032
Ult.	0.270	0.156	0.075	0.102	0.093	0.067

TABLE 8 (Cont.)

PHYSICAL PROPERTIES OF LINKS AFTER ACCELERATED AGING AND EXPOSURE TO COMMON CHEMICAL REAGENTS

	Link Material Code (See Note)					
	1	2	3	4	5	6
Links Exposed to Common Military Chemical Reagents						
7-Day Exposure Thin Film of VV-L-800 Lubricating Oil						
Tensile, Ult. lb	77	186	136	322	168	108
Elongation, in						
@35 lb	0.080	0.032	0.035	0.030	0.030	0.030
Ult.	0.246	0.085	0.074	0.131	0.073	0.055
Links Exposed to Common Military Chemical Reagents						
7-Day Exposure Spray Application of Type III, 0-I-503 Insect Repellent						
Tensile, Ult. lb	78	312	108	233	293	144
Elongation, in						
@35 lb	0.074	0.031	0.034	0.034	0.028	0.032
Ult.	0.123	0.169	0.075	0.111	0.115	0.068

Note: Links Tested are as follows:

1. Control link manufactured according to Military Specification MIL-L-45403, Link, Cartridge, Metallic Belt, 7.62mm, M13.

2. M13 style link prepared from a modified epoxy (ISOCHEM 468xx), cured with anaminoethyl piperazine type hardener.

3. M13 style link prepared from ISOCHEM 468xx filled with 30 percent glass fiber by manufacturer and cured by the aminoethyl piperazine type hardener.

4. M13 style link prepared from an epoxy, (SHELL EPON 820), cured with the aminoethyl piperazine type hardener.

5. M13 style link prepared from an epoxy, (SHELL EPON 820), cured with a metaphenylene diamine hardener.

6. M13 style link prepared from an epoxy, (SHELL EPON 820), filled with a 30 percent combination of 0.25 inch E glass and carbon fiber, flexibilized with a polyester resin, and cured with the metaphenylene diamine hardener.

TABLE 9

COMPARISON OF LINK WEIGHT CHANGE (PERCENT OF ORIGINAL) AFTER 7-DAY SOLVENT IMMERSION

Type Link (see note)	Tap Water	Saturated Water-Sodium Chloride Solution	TT-S-735 Type II Fluid	TT-S-735 Type III Fluid
1	99	99	100	100
2	111	101	101	100
3	115	112	100	100
4	104	100	101	100
5	100	100	99	100
6	100	100	100	100

Note: Same as Table 8

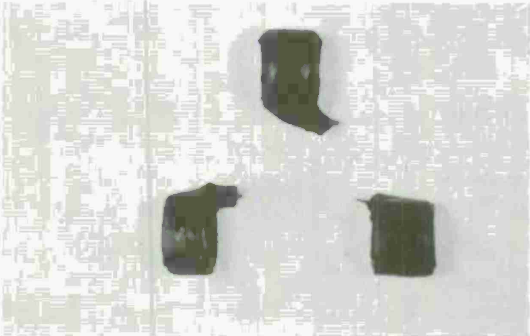
TABLE 10

COMPARISON OF LOAD-RELAXATION PROPERTIES OF PROTOTYPE PLASTIC AND CONVENTIONAL METALLIC M13 LINKS

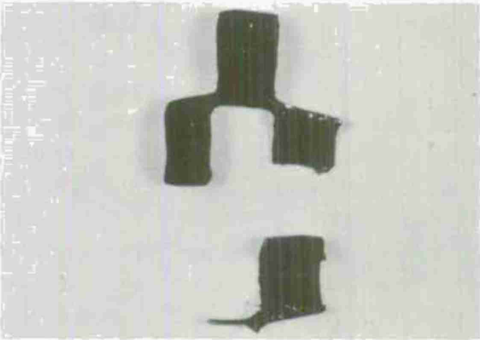
Link Material Code (see note)	Load Deflection, in. (Initial 35 lb Load)	Static Load (1 Hr. duration) Strength Loss, lb	Permanent Set, in
1	0.065	0.4	0.0010
2	0.024	4.4	0.0010
3	0.025	24.0	0.0050
4	0.024	2.8	0.0010
5	0.024	2.7	0.0010
6	0.022	2.7	0.0005

Note: Same as Table 8

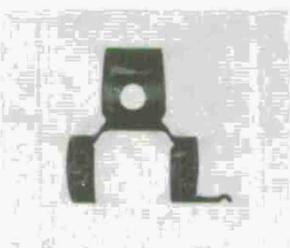
FIGURE 3. TYPICAL FAILURE PATTERN FOR CAST EPOXY AND METALLIC M13 LINKS WHEN TESTED TO ULTIMATE TENSILE LOAD



EPOXY LINK
Loop Connector Failure at 234 lb



Glass/Carbon Fiber
Reinforced Link Loop Split at 153 lb.



METALLIC M13 LINK
Center Loop Bent Open at 78 lb.

loop wall-thickness and width did not significantly affect the strength of this link. However, any reduction of the loop arch from the 0.024-square-inch cross-sectional area severely reduced ultimate link tensile strength. Fiber reinforced links failed primarily in the thin sections of the loops. Microscopic resin voids in the thin sections of these links were believed to be the cause of the premature failure under tensile loading conditions. All metallic links failed under stress loading when the center loop had sprung loose from the test mandrel.

Both plastic prototype and standard metallic M13 links were evaluated for permanent set under the 35-pound static load (1 hour) specified in Military Specification MIL-L-45403. All links, shown in Table 10, more than satisfied the 0.008 inch maximum allowable permanent set requirement, with the closed-loop plastic links elongating less than the metallic link. Strength loss after the one-hour test was slightly greater for the plastic prototype links than that loss noted for the production M13 link. Links prepared from Epon 820 epoxy resin were more resistant to permanent set than those links made from the Upox 468 epoxy resin.

CONCLUSIONS

Selected plastics reinforced with woven glass fabric had superior tensile strength when compared to unfilled material. Incorporation of woven fabrics into test links was unsuccessful.

Cut fiber reinforcements in the plastic resin reduced link elongation and tensile strength when links were prepared by low-pressure techniques. Plastic materials cast into open-loop links by laboratory methods had excessive spring yield between belted links which prevents their use in current types of automatic weapons drive mechanisms.

Of the castable materials, only the epoxy systems were found to have sufficient tensile strength and low elongation properties required of the molded link.

Epoxy plastics molded into prototype M13 closed-loop links had more than twice the tensile strength of comparable open-loop metallic links. Metallic and cast epoxy links had similar deflection and permanent set characteristics under tensile loading conditions. Plastic links eliminated rust scale deposits from forming on cartridge cases similar to those deposited by steel links after a water immersion test.

Epoxy links had adequate resistance to accelerated aging, and retained approximately 70 percent of original tensile strength after a 200-hour Weather-Ometer exposure. Cast plastic links are approximately 30 percent lighter than comparable metallic links.

The steel injection-mold (designed for the thermoplastic M13 link concepts) was not completed in time for this study, but would be applicable to the recommended product improvement program.

RECOMMENDATION

Cast epoxy resin should be considered as a potential replacement material for small-caliber links such as the 7.62mm, M13, currently made of steel.

A program to investigate injection-moldable thermoset plastics for links should be initiated.

A product improvement program to adapt plastic closed-loop links to an actual weapon system should be initiated.

Additional work should be undertaken to investigate high-strength plastic and woven fabric combinations that could adequately satisfy requirements of systems of large-caliber rounds such as the 20mm, M61 Automatic Gun, and the 30mm, XM23.

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DEVELOPMENT AND EVALUATION OF NONMETALLIC MATERIALS FOR BELT LINKS

Prepared by: Thomas J. Koehler

Technical Report R-TR-75-008

28 pages, incl Figures

Cast thin section plastics (0.70 inch) such as epoxies and urethanes reinforced with woven glass fabric had superior physical properties when compared to unfilled parent materials. None of the plastic materials tested had sufficient stiffness when cast into open-loop links to operate in current automatic weapon drive mechanisms. Epoxy resins molded into closed-loop links were more than twice as strong as current metallic link

1. Belt Links
2. Reinforced Plastic
3. Elastoplastic
4. Plastic

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